



Nucleic acids & Protein Synthesis

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Outline

- Definition of Nucleic acid
- DNA RNA
- Types of RNA
- Protein Synthesis



Nucleic acids

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graph TD; NA([Nucleic acids]) --> RNA([RNA  
(Ribonucleic acid)]); NA --> DNA([DNA  
(Deoxyribonucleic acid)]); RNA --> mRNA([mRNA]); RNA --> rRNA([rRNA]); RNA --> tRNA([tRNA]);
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RNA
(Ribonucleic acid)

DNA
(Deoxyribonucleic acid)

mRNA

rRNA

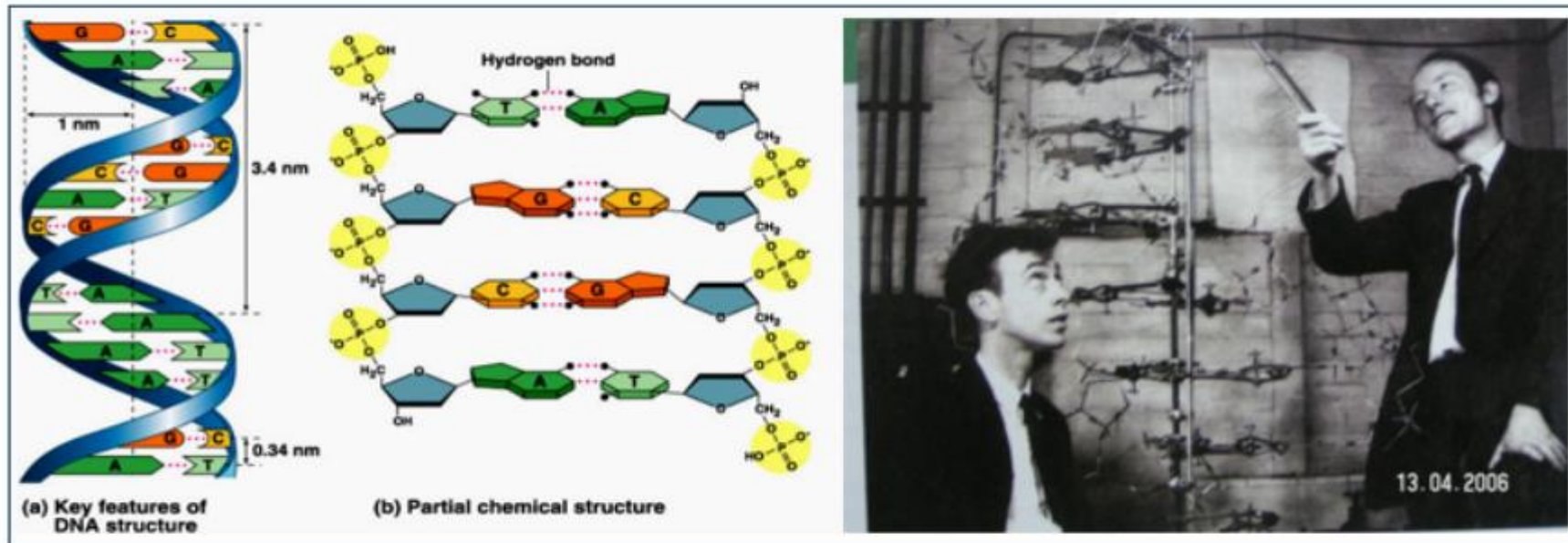
tRNA

Nucleic acids

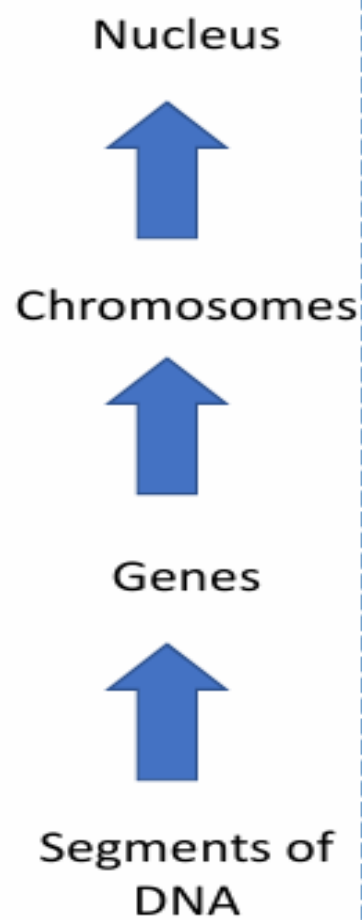
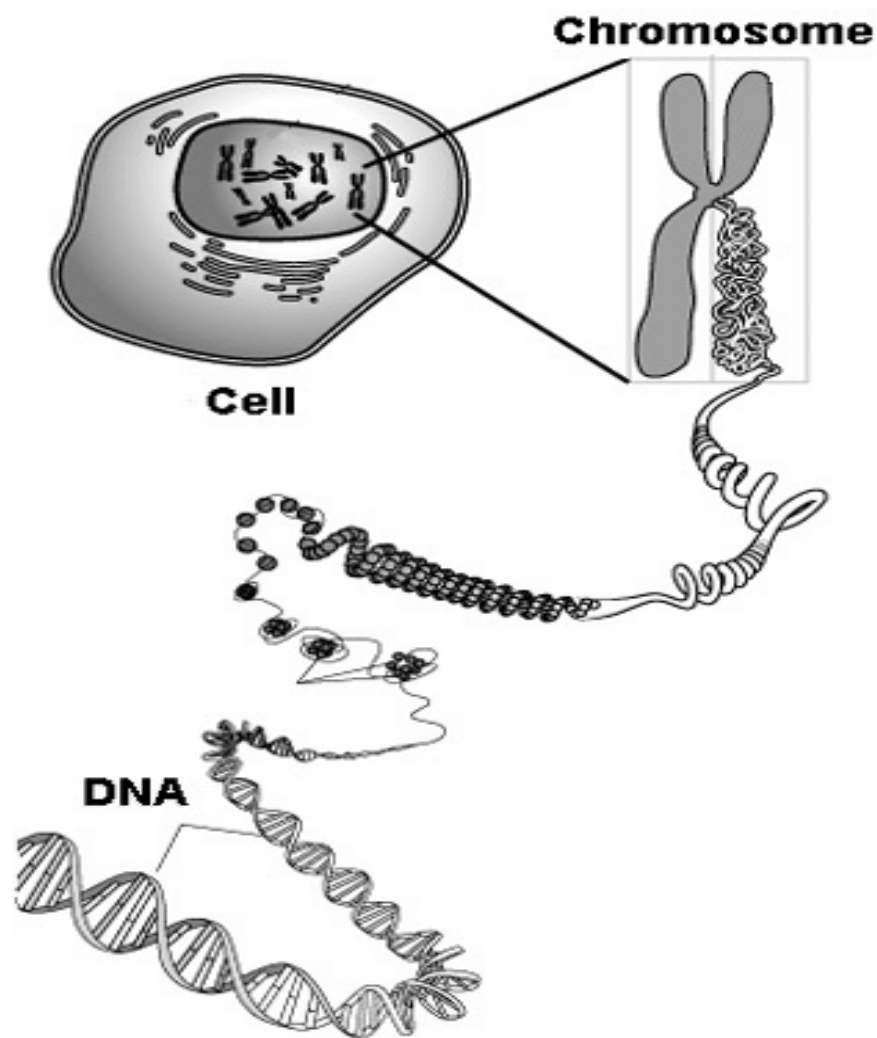
- Nucleic acids are biological macromolecules that store and transmit genetic information.
- They're composed of repeating units called nucleotides, which contain three components: a sugar molecule, a phosphate group, and a nitrogenous base.
- These molecules are essential for all known forms of life, serving as the blueprint for inheritance and the instructions for building proteins.

DNA: The Double Helix

- DNA was first identified in 1869 by Swiss chemist Friedrich Miescher, who called it "nuclein" while studying white blood cells.
- Its structure as a double helix was discovered in 1953 by James Watson and Francis Crick using X-ray data .



Deoxyribonucleic Acid



Portions of DNA are called genes.

DNA is tightly wound into chromosomes and located in the nucleus of cells.

DNA cannot leave the nucleus.

DNA is **DOUBLE STRANDED**(2 sides)

DNA Structure

*The building blocks of DNA are called Nucleotides.

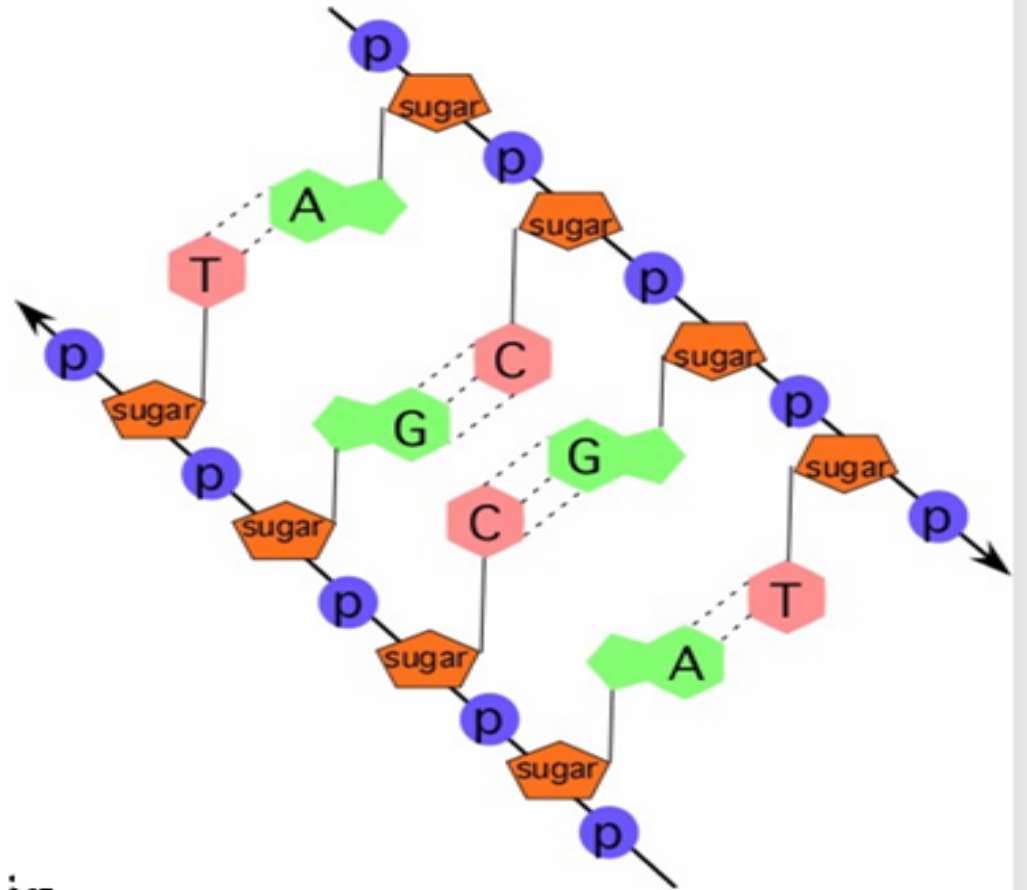
* One nucleotide is made of 3 important things:

1. 5-Carbon Sugar Deoxyribose
2. Phosphate
3. Nitrogen base

there are 4 nitrogen bases in DNA: Adenine, Guanine, Cytosine, and Thymine that pair together)

A → T

C → G



Ribonucleic acid (RNA)

- Ribonucleic acid (RNA) is a polymeric molecule essential in various biological roles in coding, decoding, regulation, and expression of genes.
- RNA and DNA are nucleic acids, and, along with lipids, proteins and carbohydrates, constitute the four major macromolecules essential for all known forms of life.
- Like DNA, RNA is assembled as a chain of nucleotides, but unlike DNA it is more often found in nature as a single-strand folded onto itself, rather than a paired double-strand.
- Cellular organisms use messenger RNA (mRNA) to convey genetic information (using the nitrogenous bases of guanine, uracil, adenine, and cytosine, denoted by the letters G, U, A, and C) that directs synthesis of specific proteins.
- Many viruses encode their genetic information using an RNA genome.

RNA Structure

* The building blocks of RNA are Nucleotides, just like DNA.

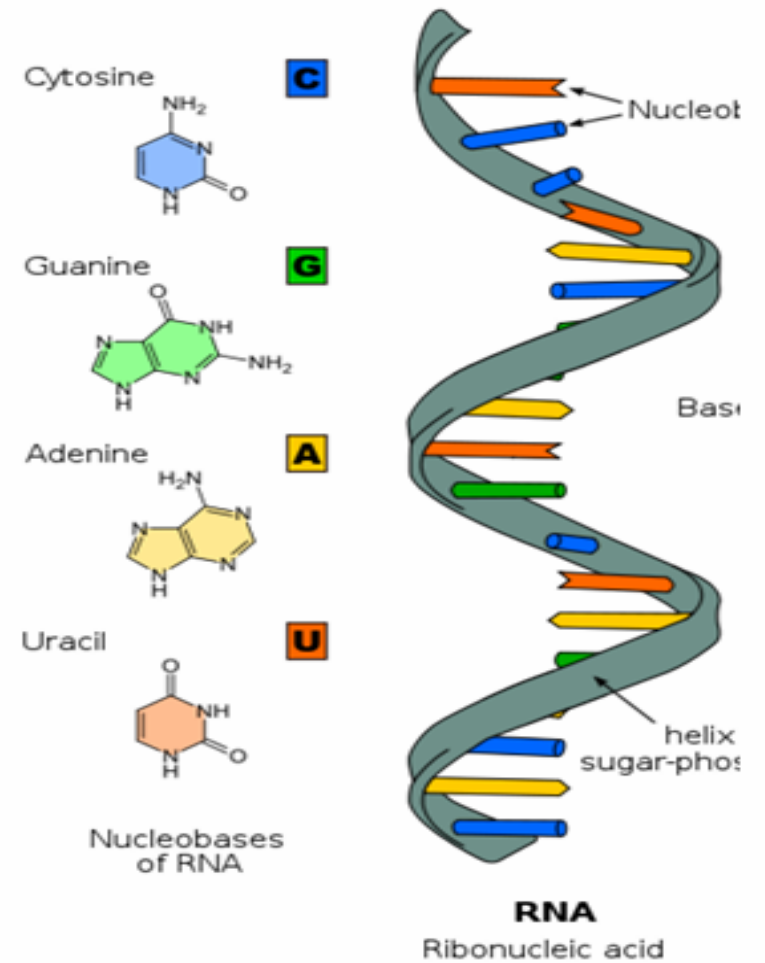
* A Nucleotide in RNA is still made of 3 important things:

1. 6-Carbon Sugar - Ribose (instead of Deoxyribose)
2. Phosphate
3. Nitrogen base

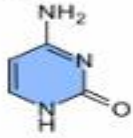
there are 4 nitrogen bases in RNA, A, G, C, and U that pair together)

A → U

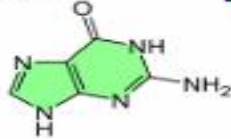
C → G



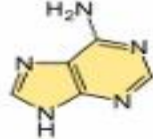
Cytosine **C**



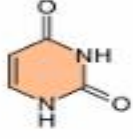
Guanine **G**



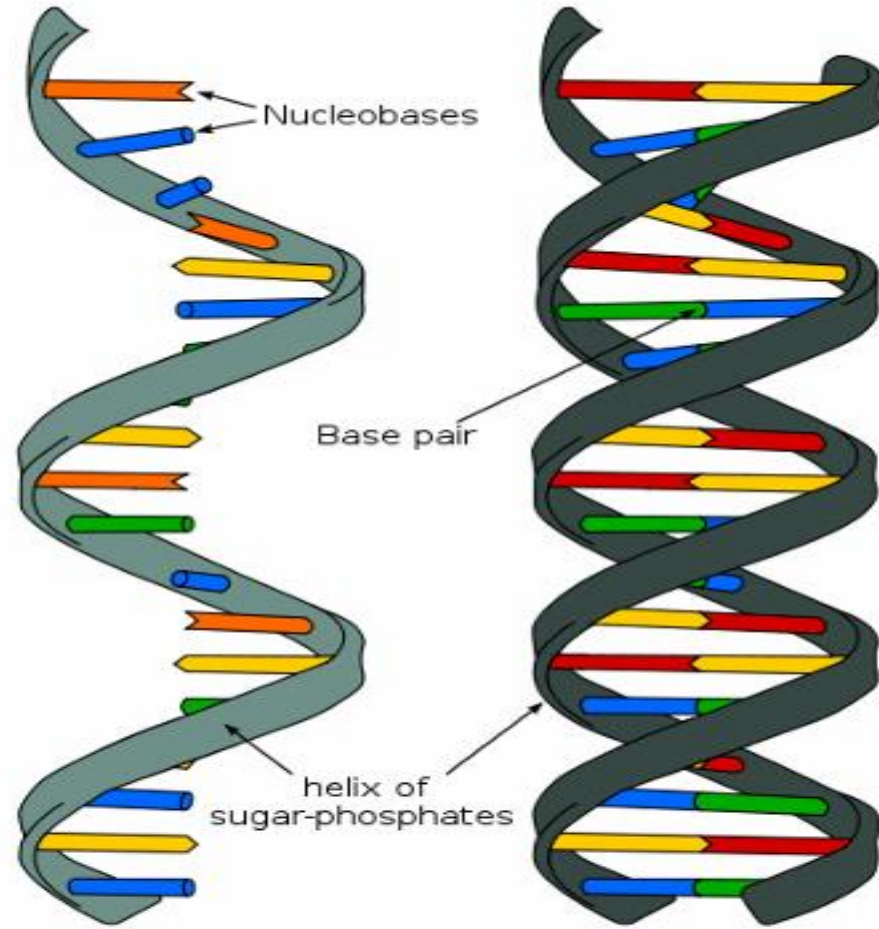
Adenine **A**



Uracil **U**



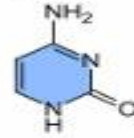
Nucleobases
of RNA



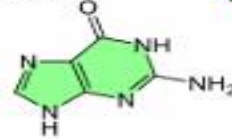
RNA
Ribonucleic acid

DNA
Deoxyribonucleic acid

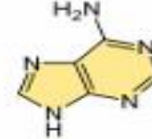
Cytosine **C**



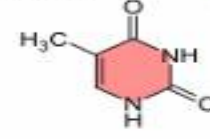
Guanine **G**



Adenine **A**

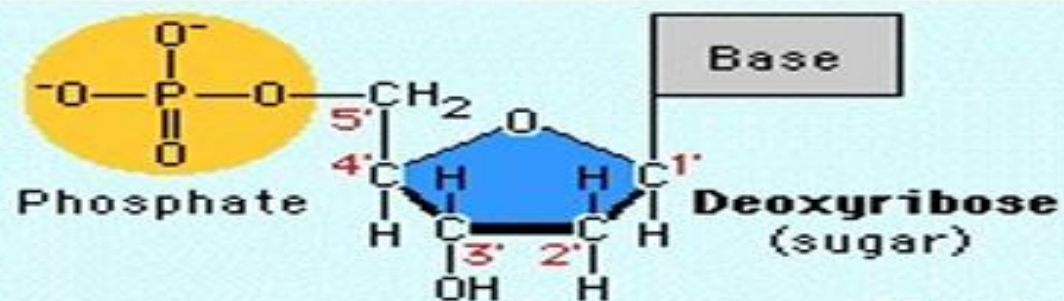


Thymine **T**

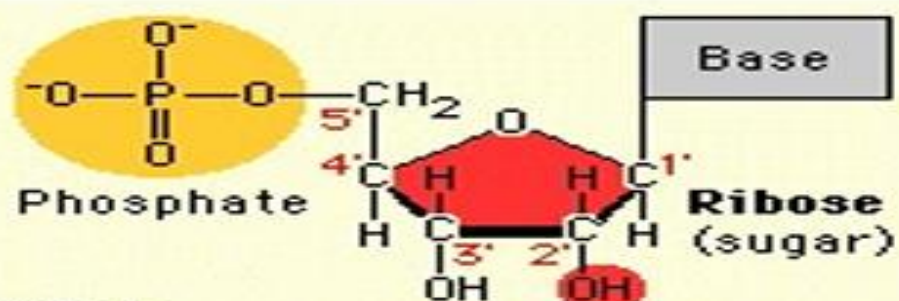


Nucleobases
of DNA

DNA



RNA

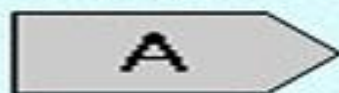


Nucleotides

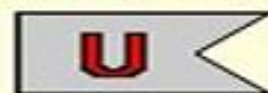
Pyrimidines



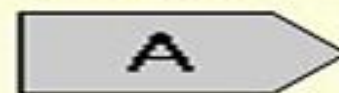
Purines



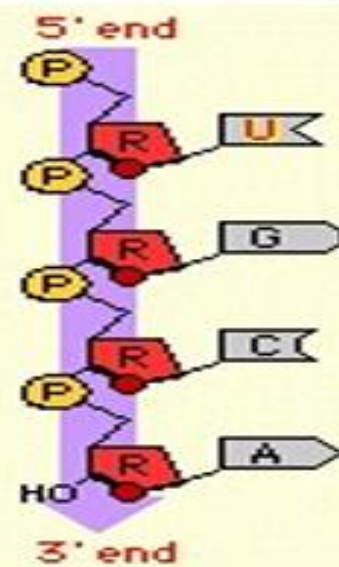
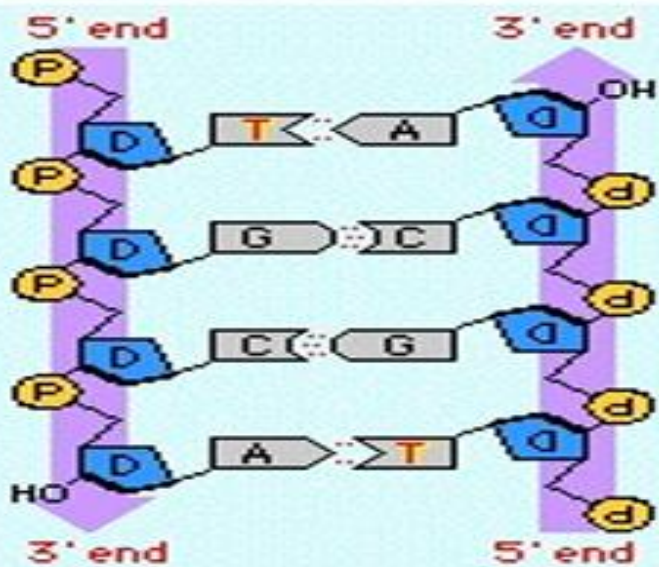
Pyrimidines



Purines



Bases



Polynucleotides

Types of RNA

There are three major types of RNA that participate in the process of protein synthesis: rRNA, tRNA, and mRNA.

Like DNA, these three types of RNA are unbranched polymeric molecules composed of nucleoside monophosphates joined together by 3'→5'-phosphodiester bonds.

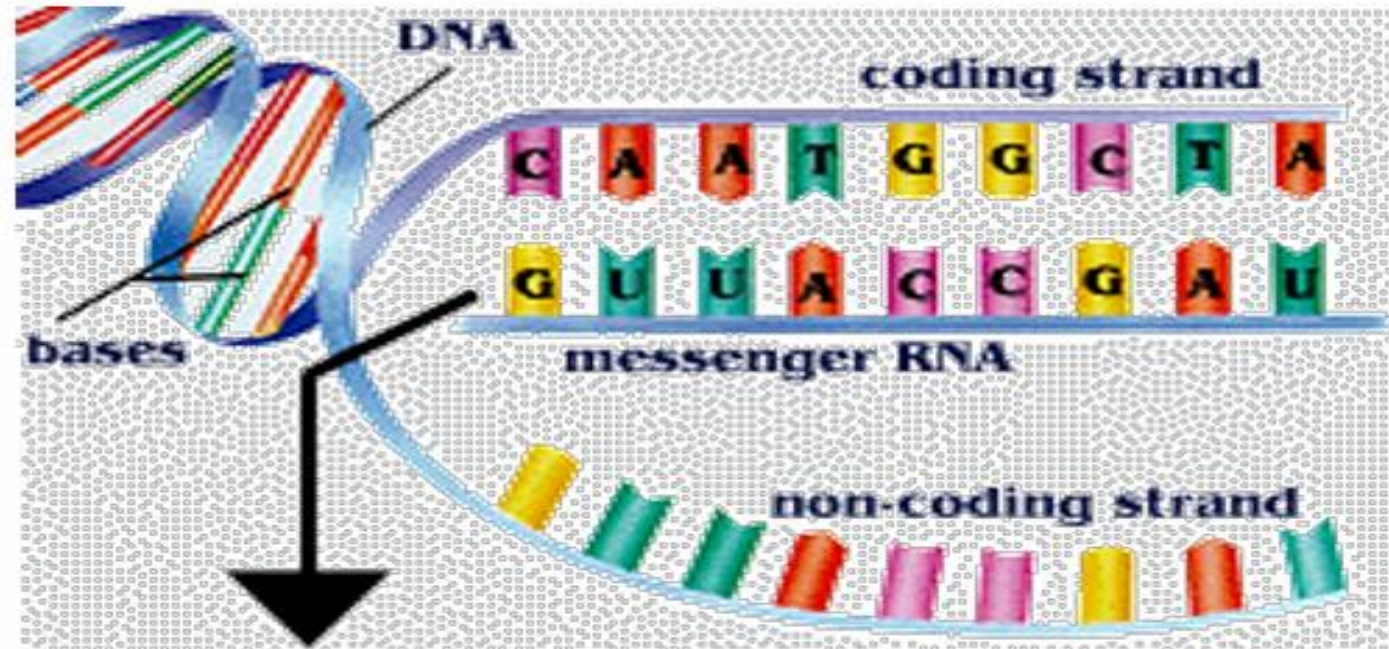
However, they differ from DNA in several ways.

For example, they are considerably smaller than DNA, contain ribose instead of deoxyribose and uracil instead of thymine, and exist as single strands that are capable of folding into complex structures.

The three major types of RNA also differ from each other in size, function, and special structural modifications.

Three Main Types of RNA

1. Messenger RNA (mRNA) - Carries copies of instructions for the assembly of amino acids into proteins from DNA to the rest of the cell (serve as “messenger”)



Three Main Types of RNA

2. Ribosomal RNA (rRNA) – Makes up the major part of ribosomes, which is where proteins are made.

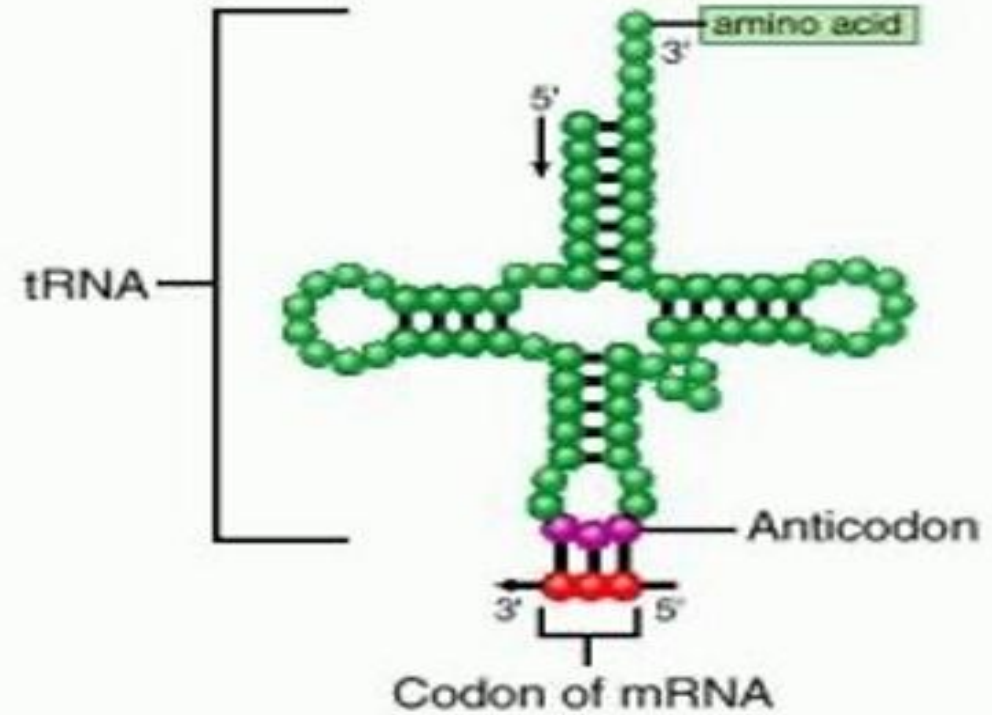
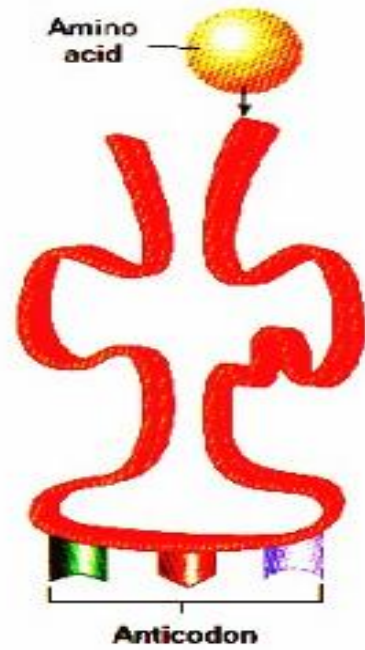
**Ribosomal
RNA**



Three Main Types of RNA

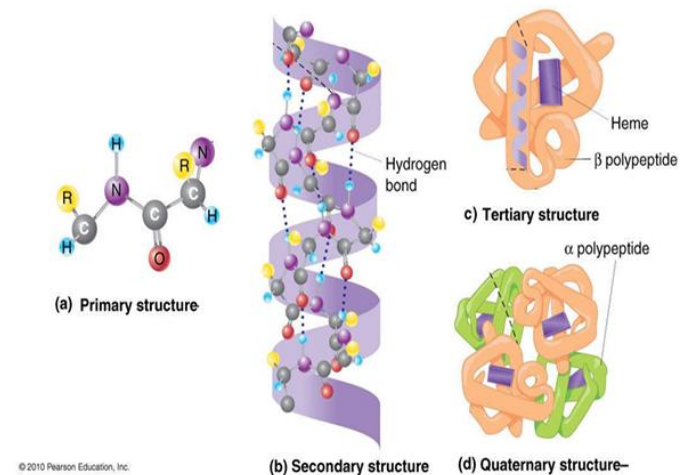
- 3. Transfer RNA (tRNA) - Transfers amino acids to ribosomes during protein synthesis

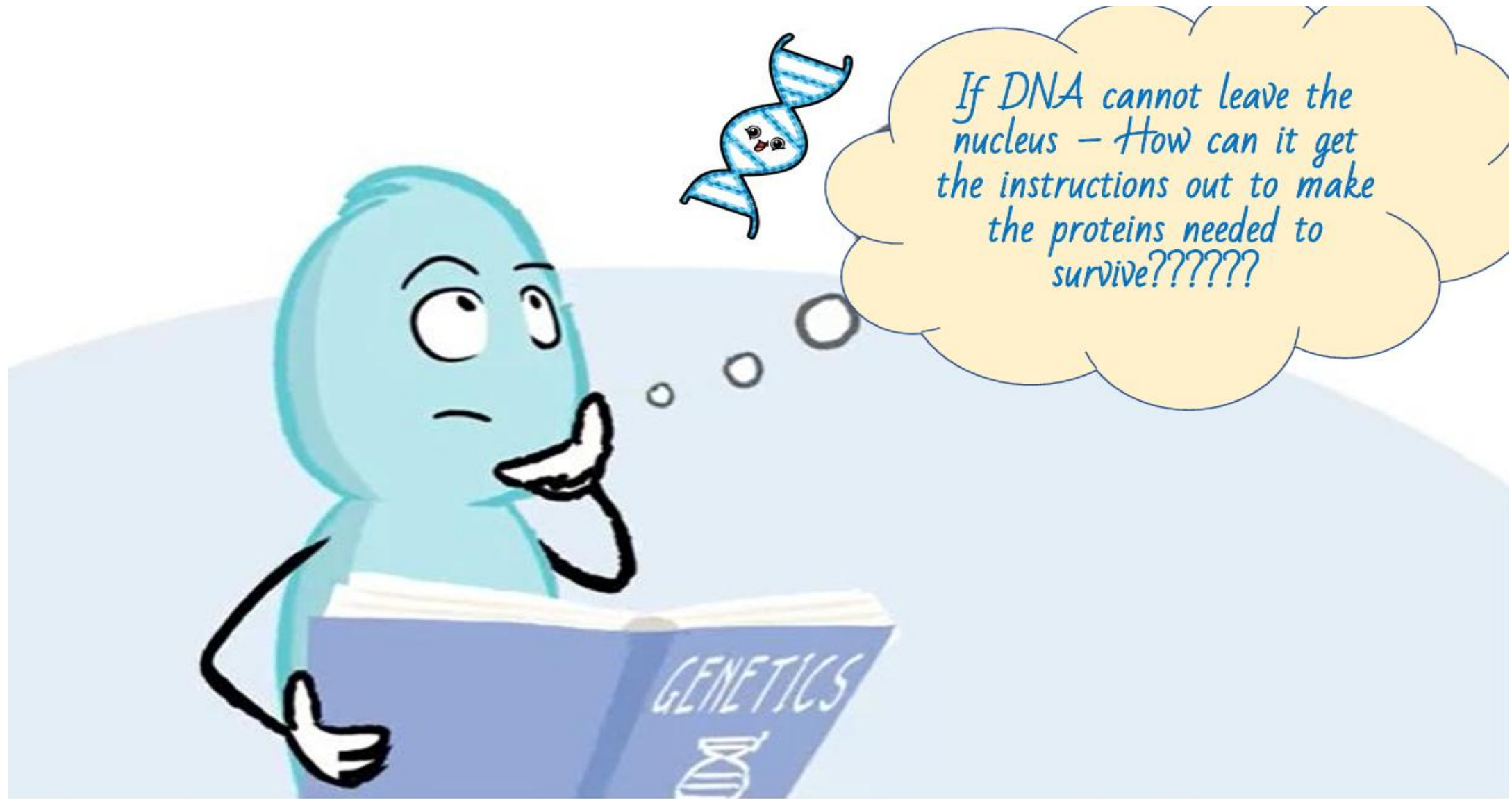
Transfer RNA



proteins

- Proteins (also known as polypeptides) are made of amino acids arranged in a linear chain and folded into a globular form.
- The sequence of amino acids in a protein is defined by the sequence of a gene which is encoded in the genetic code
- Genetic code specifies 20 standard amino acids .





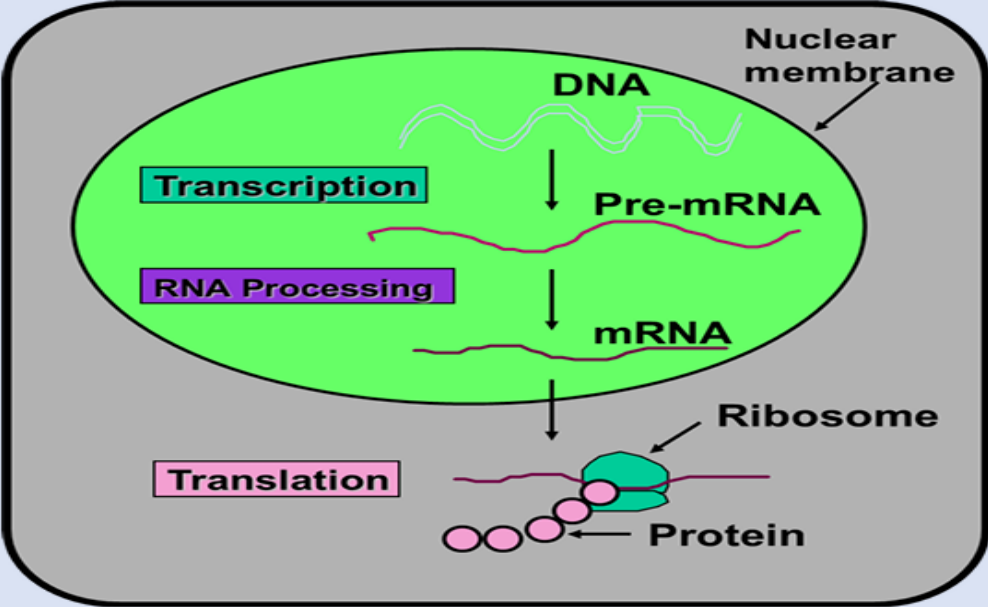
If DNA cannot leave the nucleus - How can it get the instructions out to make the proteins needed to survive?????

Protein synthesis

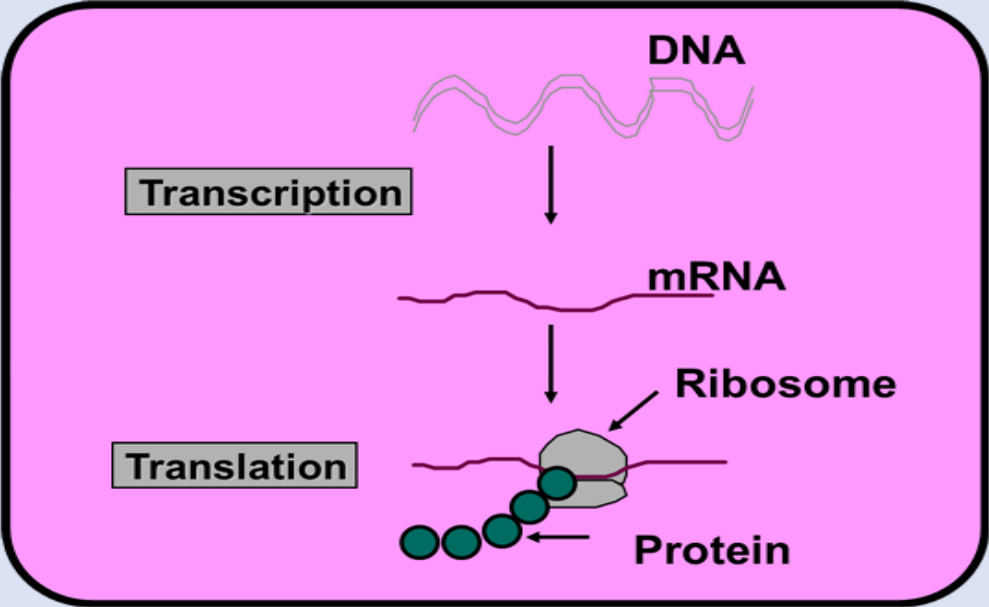
- Definition: Is the process in which polypeptide chains are formed from coded combinations of single amino acids (AA) inside the cell.
- The synthesis of new polypeptides requires a coded sequence, enzymes, and mRNA, rRNA, and tRNA.
- Protein synthesis takes place within the nucleus and ribosomes of a cell and is regulated by DNA and RNA.
- Protein synthesis, consists of two processes — transcription and translation.
- In eukaryotic cells, transcription takes place in the nucleus. While translation occurs in ribosomes that located either free floating in the cytoplasm or attached to the endoplasmic reticulum.
- In prokaryotic cells, which lack a nucleus, the processes of both transcription and translation occur in the cytoplasm.

Protein synthesis

DNA → RNA → Protein



Eukaryotic Cell

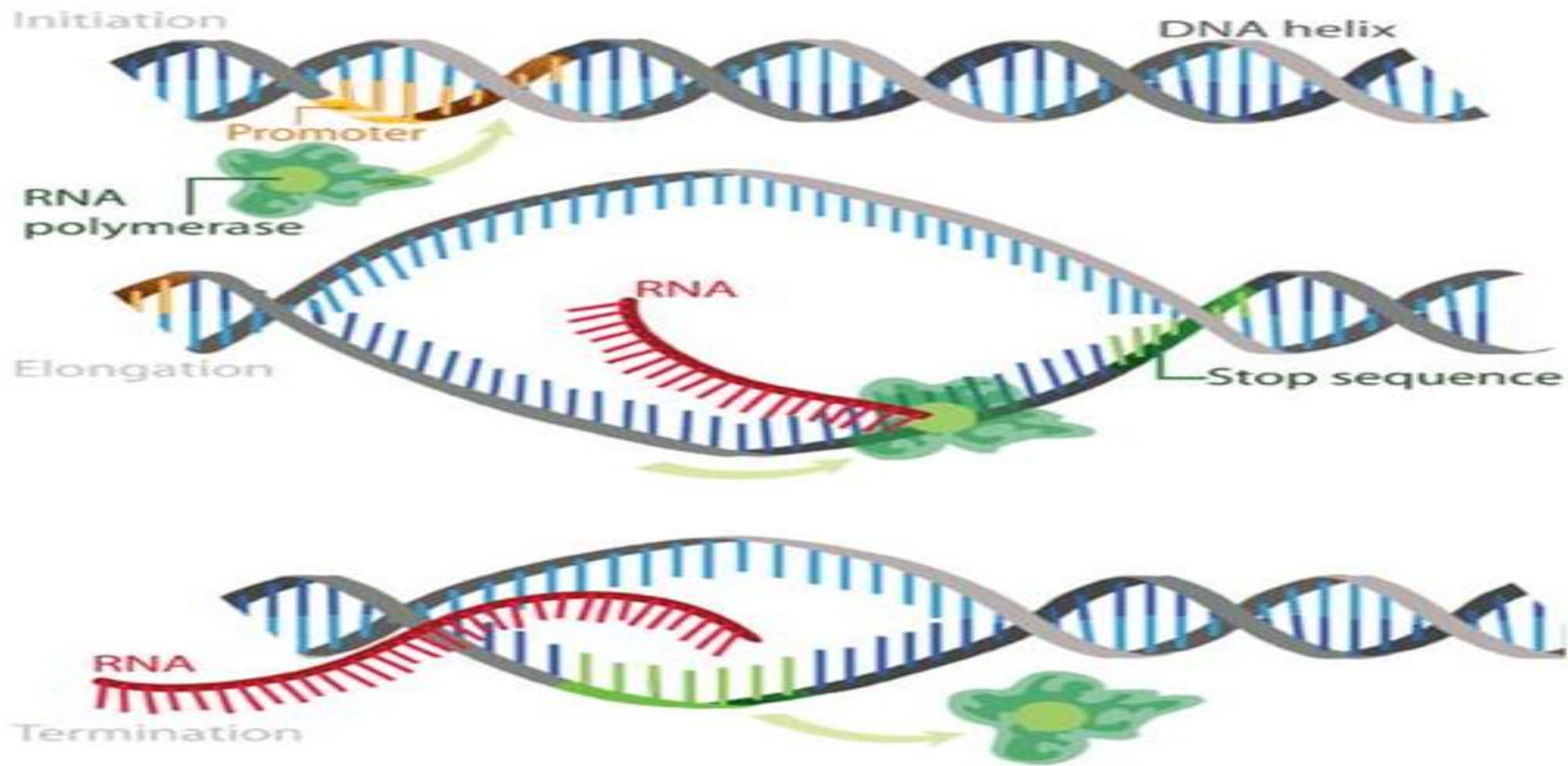


Prokaryotic Cell

mRNA must be processed before it leaves the nucleus of eukaryotic cells.

Protein synthesis in eukaryotic cells

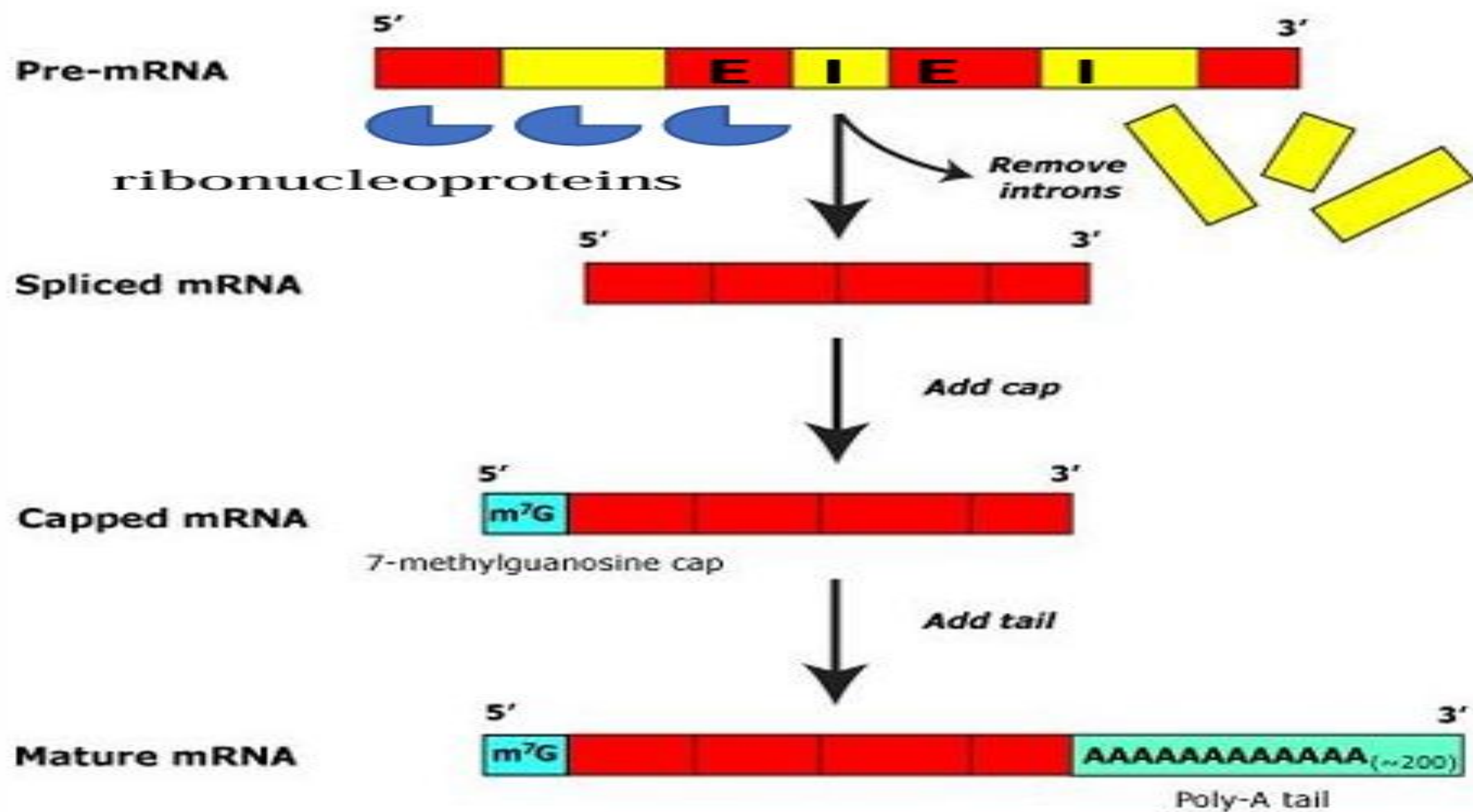
- Transcription: DNA is used as a template to make a molecule of messenger RNA(mRNA). It is the transfer of genetic instructions in DNA to mRNA (a strand of mRNA is made to complement a strand of DNA).
- **Steps of Transcription:**
- Transcription takes place in nucleus and it's three steps:
- initiation, elongation, and termination.
- **a. Initiation** is the beginning of transcription. It occurs when the enzyme RNA polymerase binds to a region of a gene called the promoter.
- This signals DNA to unwind so the enzyme can “read” the bases in one of the DNA strands. The enzyme is ready to make a strand of mRNA with a complementary sequence of bases.
- **b. Elongation** is the addition of nucleotides to the mRNA strand.
- **c. Termination** is the ending of transcription. The mRNA strand is complete, and it detaches from DNA.



Processing mRNA

- The new mRNA is not yet ready for translation.
- At this stage, it is called pre-mRNA, and it must go through more processing before it leaves the nucleus as mature mRNA.
- The processing may include splicing, editing, and polyadenylation coding sequence just for one polypeptide.
- • **Splicing** removes introns from mRNA.
- Introns are regions that do not code for the protein.
- The remaining mRNA consists only of regions called exons that do code for the protein. The ribonucleoproteins are small proteins in the nucleus that contain RNA and are needed for the splicing process.

- **Editing** changes some of the nucleotides in mRNA. For example, a human protein called APOB, which helps transport lipids in the blood, has two different forms because of editing.
- One form is smaller than the other because editing adds an earlier stop signal in mRNA.
- • **Polyadenylation** adds a “tail” to the mRNA on 3’ position. The tail consists of a string of As (adenine bases). It signals the end of mRNA. It is also involved in exporting mRNA from the nucleus, and it protects mRNA from enzymes that might break it down.

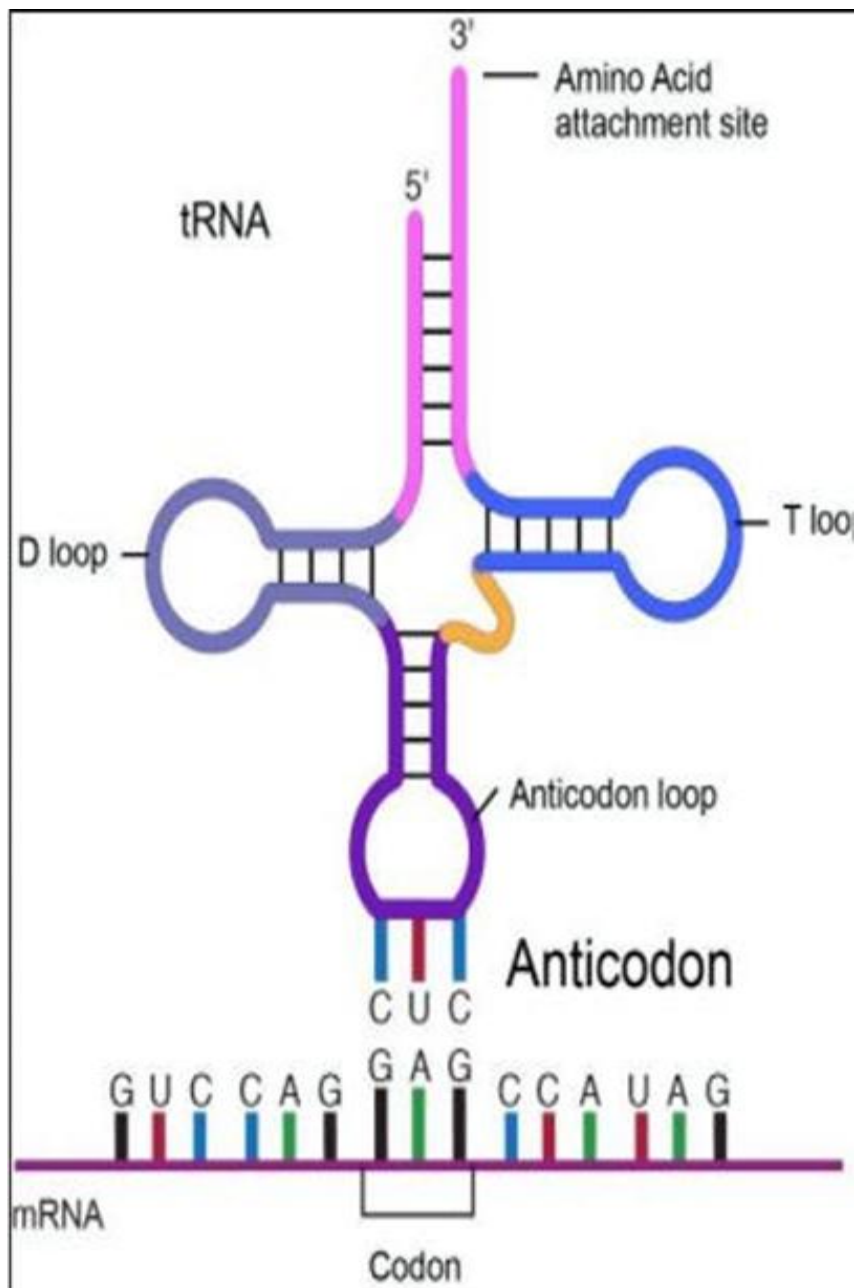


Translation

- It is the process in which the genetic code in mRNA is read to make a protein.
- After mRNA leaves the nucleus, it moves to a ribosome, which consists of rRNA and proteins.

The ribosome reads the sequence of codons in mRNA, and molecules of tRNA bring amino acids to the ribosome in the correct sequence.

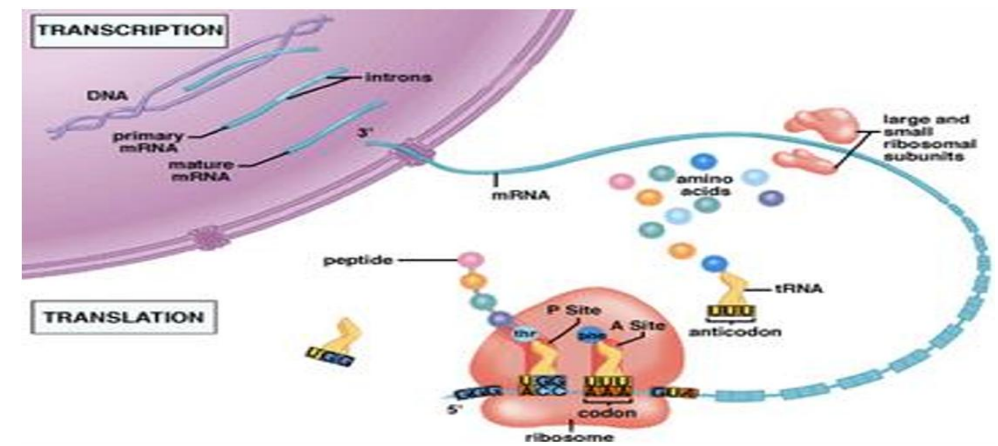
- • Each tRNA molecule has an anticodon for the amino acid it carries.
- An anticodon is complementary to the codon for an amino acid.
- For example, the amino acid lysine has the codon AAG, so the anticodon is UUC. Therefore, lysine would be carried by a tRNA molecule with the anticodon UUC.
- Wherever the codon AAG appears in mRNA, a UUC anticodon of tRNA temporarily binds. While bound to mRNA, tRNA gives up its amino acid.
- With the help of rRNA, bonds form between the amino acids as they are brought one by one to the ribosome, creating a polypeptide chain.
- The chain of amino acids keeps growing until a stop codon is reached.



		Second letter					
		U	C	A	G		
First letter	U	UUU } Phe UUC } UUA } Leu UUG }	UCU } UCC } Ser UCA } UCG }	UAU } Tyr UAC } UAA Stop UAG Stop	UGU } Cys UGC } UGA Stop UGG Trp	U C A G	
	C	CUU } CUC } Leu CUA } CUG }	CCU } CCC } Pro CCA } CCG }	CAU } His CAC } CAA } Gln CAG }	CGU } CGC } Arg CGA } CGG }	U C A G	
	A	AUU } AUC } Ile AUA } AUG Met	ACU } ACC } Thr ACA } ACG }	AAU } Asn AAC } AAA } Lys AAG }	AGU } Ser AGC } AGA } Arg AGG }	U C A G	
	G	GUU } GUC } Val GUA } GUG }	GCU } GCC } Ala GCA } GCG }	GAU } Asp GAC } GAA } Glu GAG }	GGU } GGC } Gly GGA } GGG }	U C A G	

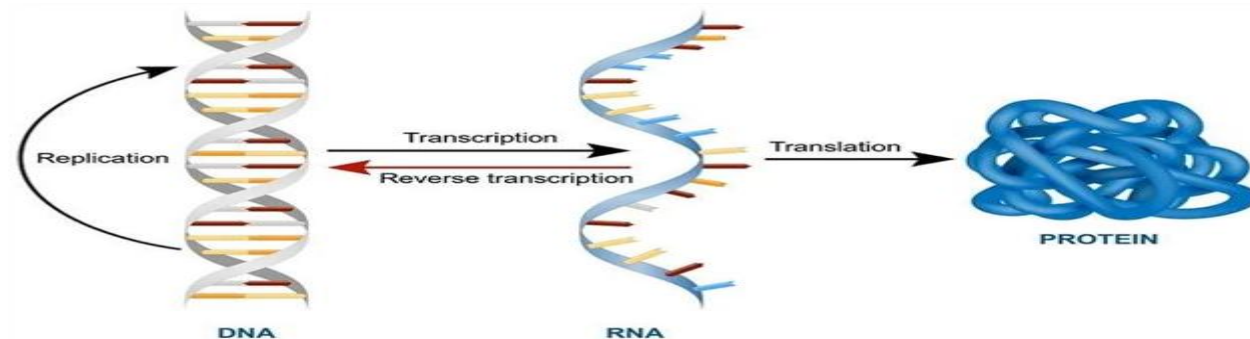
- Protein synthesis (or translation) takes place in three stages: Initiation, Elongation, and Termination
- 1. **Initiation:**
 - • The first step is the formation of a **pre-initiation complex** consisting of the small ribosomal subunit, GTP (that acts as an energy source) and other initiation factors.
 - • The pre-initiation complex binds to the 5' end of the eukaryotic mRNA.
 - • The complex then moves along the mRNA in a 5' to 3' direction until it locates the **AUG initiation codon** (i.e., scanning) which is methionine (Met)
 - • Once the complex is positioned over the initiation codon, the large ribosomal subunit binds to form an initiation complex, a step that requires the hydrolysis of GTP and leads to the release of several initiation factors.

- 2. Elongation:
 - • Elongation depends on eukaryotic elongation factors.
 - • At the end of the initiation step, the mRNA is positioned so that the next codon can be translated during the elongation stage of protein synthesis.
 - • The initiator tRNA occupies the P site in the ribosome, and the A site is ready to receive an aminoacyl-tRNA.



- 3. Termination:
- • Termination of elongation depends on eukaryotic release factors.
- • In eukaryotes, eukaryotic release factor eRF-1 recognizes all three termination (stop) codons (UAA, UAG and UGA) and, with the help of a type of protein, terminates translation.
- • Upon termination, the ribosome is dissociated, and the completed polypeptide is released.

- After a polypeptide chain is synthesized, it may undergo additional processes. For example, it may assume a folded shape due to interactions between its amino acids. It may also bind with other polypeptides or with different types of molecules, such as lipids or carbohydrates. Many proteins travel to the Golgi apparatus within the cytoplasm to be modified for the specific job they will do.





Thank
you